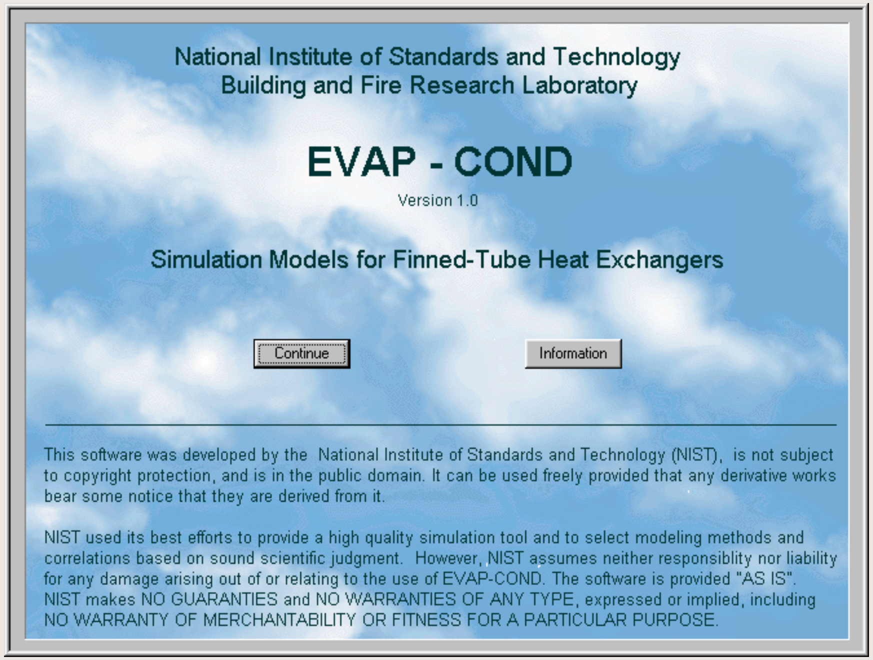
EVAP- COND INSTRUCTIONS

EVAP-COND is a software package that contains NIST's **EVAP** and **COND** simulation models for a finned-tube evaporator and condenser. The following pages provide basic instructions on how to use this package. The instructions include software installation, preparation of input data, execution of the program, examination of simulation results, and general information on the package design.

EVAP-COND capabilities include:

- Tube-by-tube simulation
- One-dimensional, non-uniform air distribution
- Simulation of refrigerant distribution
- Condenser model capable of simulating above the critical point
- REFPROP7 refrigerant properties
- 10 refrigerants and refrigerant mixtures: R22, R32, R134a, R290, R404A, R407C, R410A, R507A, R717, and R744.



October 31, 2002

HOW TO PROCEED

These Instruction Pages will help you to understand capabilities of EVAP-COND. We recommend that you proceed through them sequentially. You will benefit most if you print these pages, install EVAP-COND, and follow the example for evaporator simulation on your computer.

Only rudimentary information on the evaporator and condenser models is provided. For more detailed information the reader should refer to the List of References, where several references are provided. The latest validation of EVAP and COND for R22 and R410A evaporators and condensers is presented in Domanski and Payne (2002).

INSTALLATION

System Requirements

Free space for complete installation: 35 MB

PC with Microsoft Windows (TM) 98, 2000, Me, NT, or XP

Printer: optional and should be Windows compatible

Memory required: at least 64 MB

Installation Procedure

1. Download the self-extracting file ***Ev-Cd.exe*** to a folder of your choice and execute* it. This will extract the files you need to continue EVAP-COND installation.

2. Execute* ***Startup.exe*** installation module and follow installation instructions as they appear on the screen.

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* To execute a file, locate the file in the folder and double-click on it, or click on the Start button, select Run, use the Browse key to locate the file or type the file name in the entry box (preceded by the full path).

The installation process will a) install the EVAP-COND package in the folder of your designation. The name of the executable file is ***EVAP-COND.EXE***

b) create the EVAP-COND startup group accessible from the Start button

c) create the EVAP-COND shortcut and place an icon on the desk top

To enable functionality of b) and c) for Win98, Me and some NT systems, you will have to download and install a patch "Microsoft Active Accessibility 2.0 Redistributable" from Microsoft's web site .

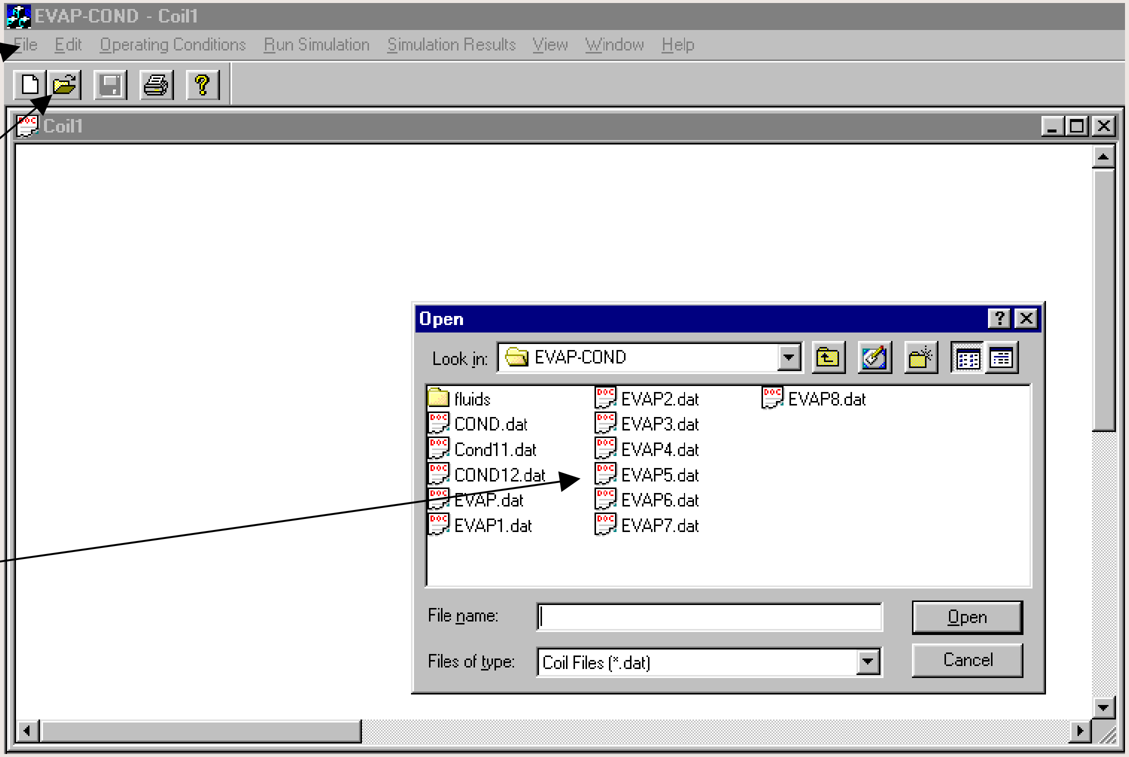
LOADING A FILE

After starting the program, click on the "open file" button on the power bar or select *Open* on the *File* pull down menu.

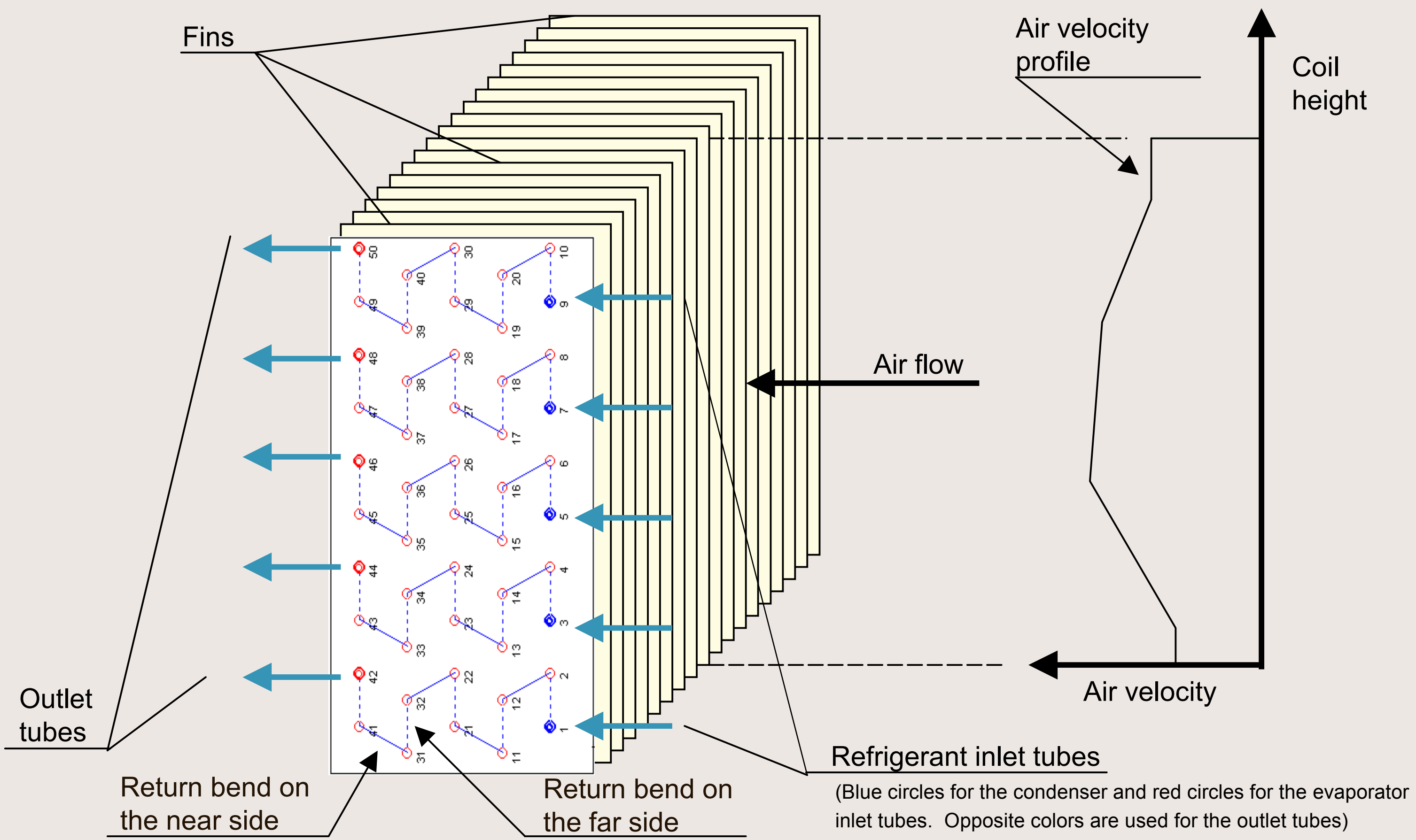
Open file EVAP5.dat to continue this tutorial.

A side view of the evaporator will appear.

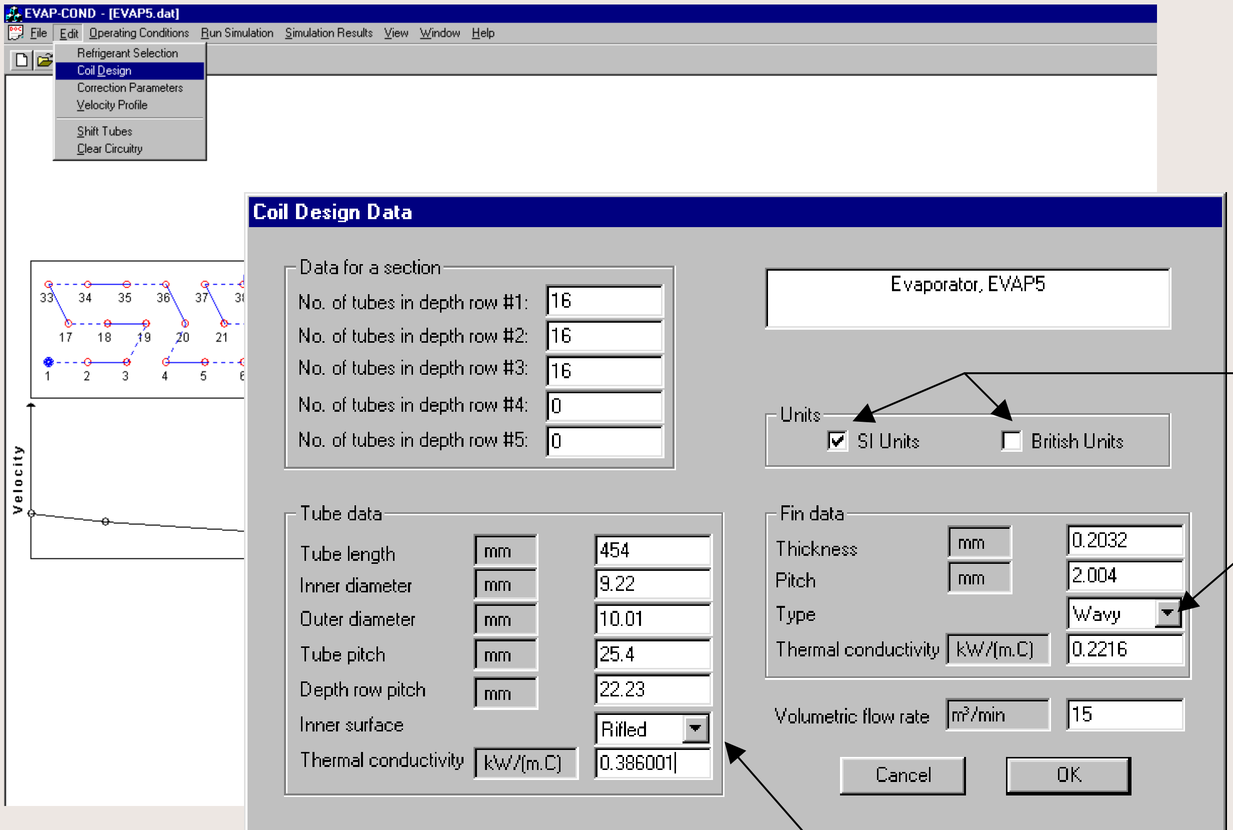
The next page presents the concept of heat exchanger representation in EVAP-COND.



HEAT EXCHANGER REPRESENTATION



COIL DESIGN DATA



The system of units for data input and output can be selected here.

Flat, wavy, lanced, and louver fins are available.

Smooth and rifled tubes are available.

REFRIGERANT CIRCUITRY DESIGN

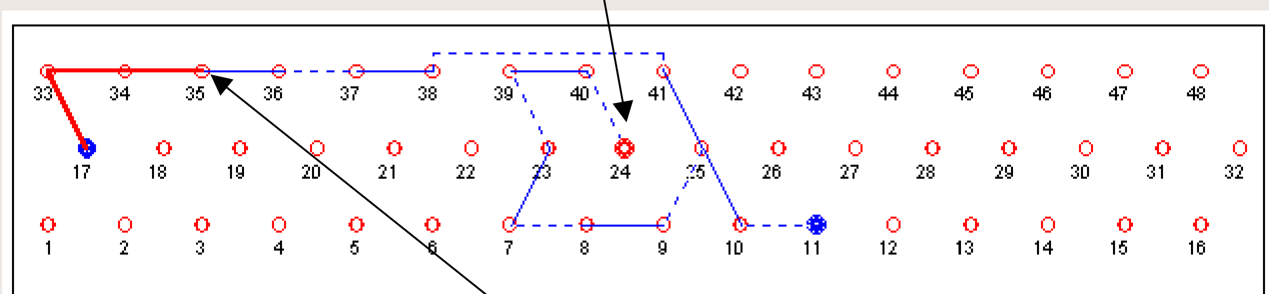
The refrigerant circuitry was already specified in EVAP5 file we loaded for this tutorial. If we had not loaded an existing file and entered coil design data, as shown in the previous slide, a rectangle would appear with circles denoting tubes in the coil assembly. Then we would proceed to specify a refrigerant circuitry.

Follow the steps below to design a circuitry:

1. Place the pointer on the tube
2. Press the left mouse button
3. Drag the pointer to the next tube
4. Release the left button.

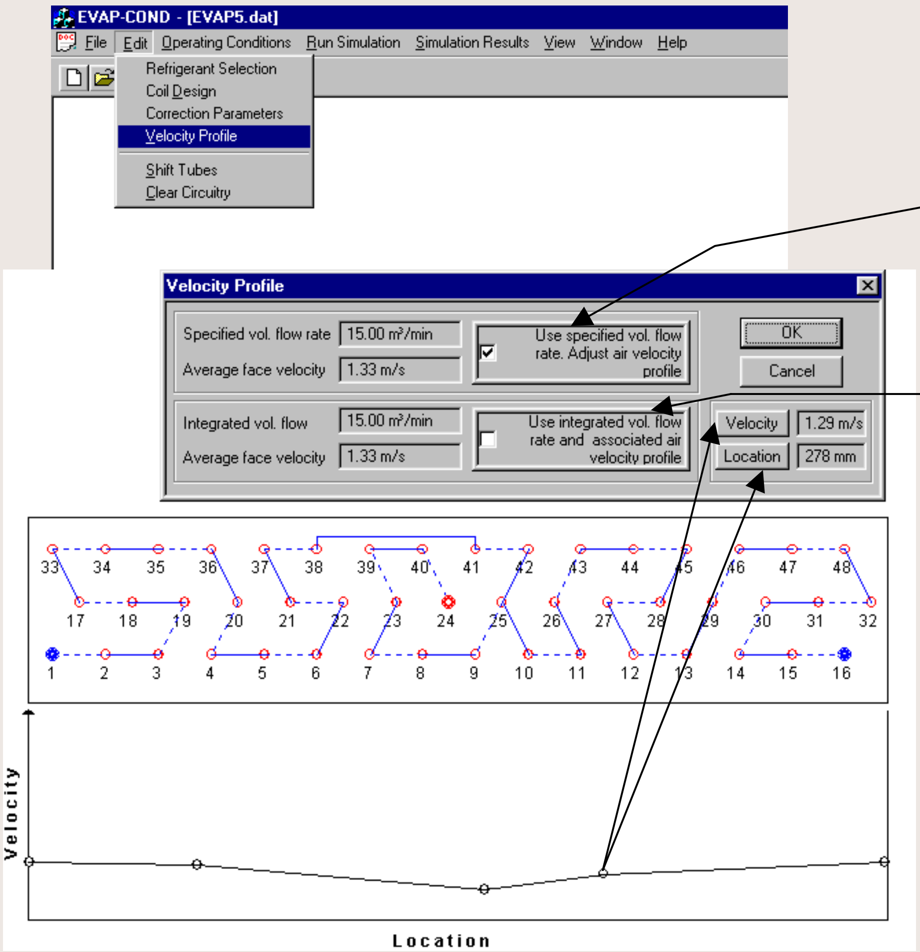
Note: Start with the inlet tube for the evaporator.
Start with the outlet tube for the condenser.

Evaporator inlet tube



Option: You may remove a part of the circuit by positioning the pointer on a given tube and clicking twice with the left button.

AIR VELOCITY PROFILE



Recall that the coil design data included the volumetric flow rate of air. Before you leave this window you must decide between the two options:

- to use the previously specified volumetric flow rate and have the velocity profile scaled to match that value (recommended)

or

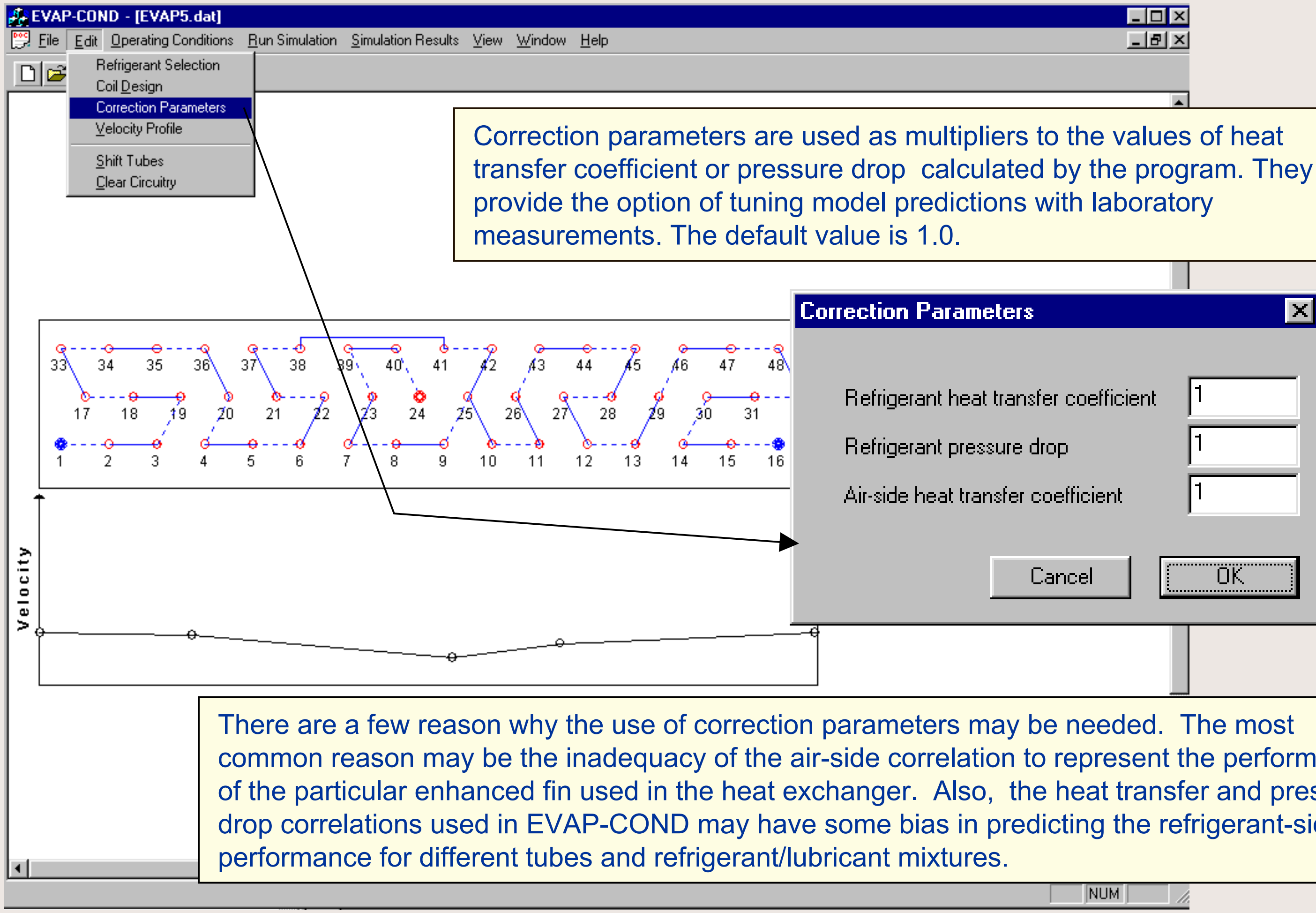
- to disregard the previously specified volumetric flow rate and calculate a new volumetric flow rate from the velocity profile

To specify velocity at a given point, place the pointer at that point and left click. The window above shows the coordinates. Up to sixteen velocity points may be specified.

Click on a given point to remove it.

The *Velocity Profile* window must be open to make air velocity profile changes.

CORRECTION PARAMETERS

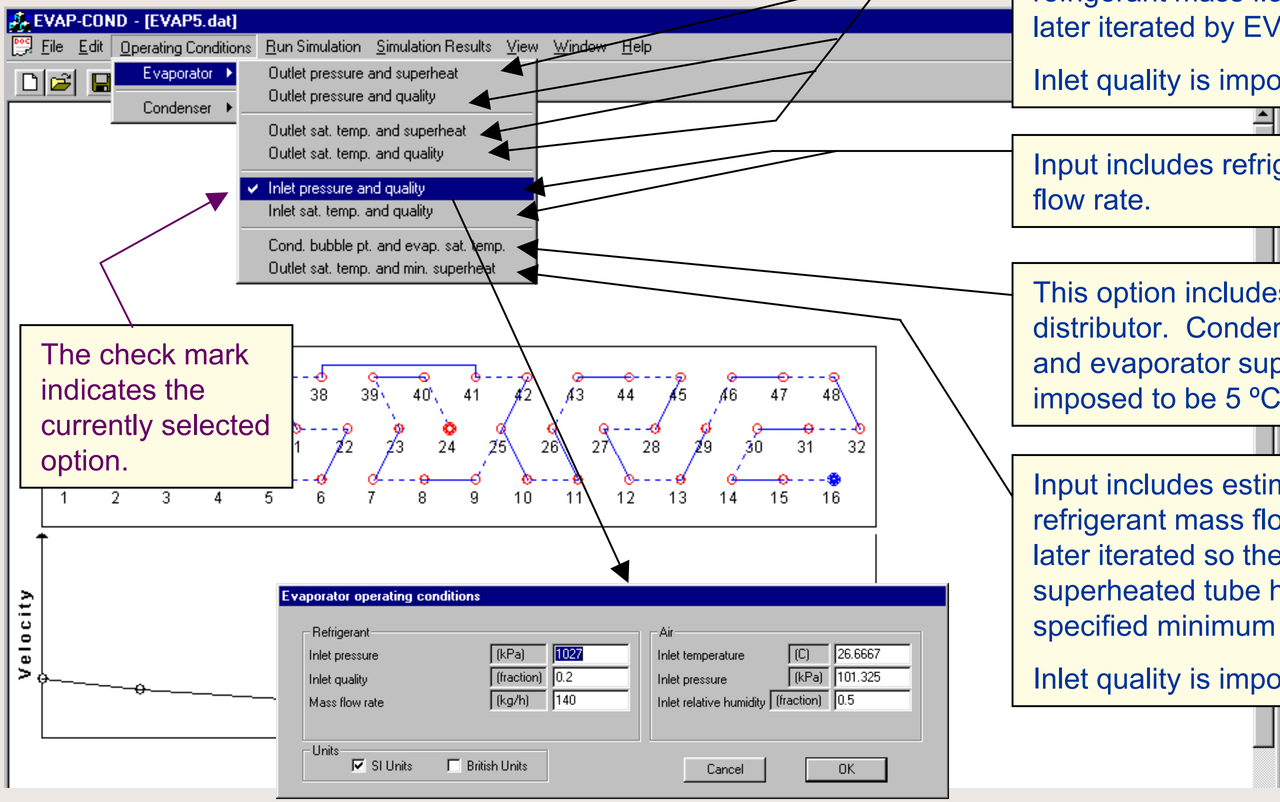


Correction parameters are used as multipliers to the values of heat transfer coefficient or pressure drop calculated by the program. They provide the option of tuning model predictions with laboratory measurements. The default value is 1.0.

There are a few reason why the use of correction parameters may be needed. The most common reason may be the inadequacy of the air-side correlation to represent the performance of the particular enhanced fin used in the heat exchanger. Also, the heat transfer and pressure drop correlations used in EVAP-COND may have some bias in predicting the refrigerant-side performance for different tubes and refrigerant/lubricant mixtures.

EVAPORATOR OPERATING CONDITIONS

Eight options for operating conditions are available for evaporator simulations. All input options include air inlet temperature, pressure, and relative humidity, but they use different refrigerant parameters.



Input includes estimated refrigerant mass flow rate, which is later iterated by EVAP5.

Inlet quality is imposed at 0.20.

Input includes refrigerant mass flow rate.

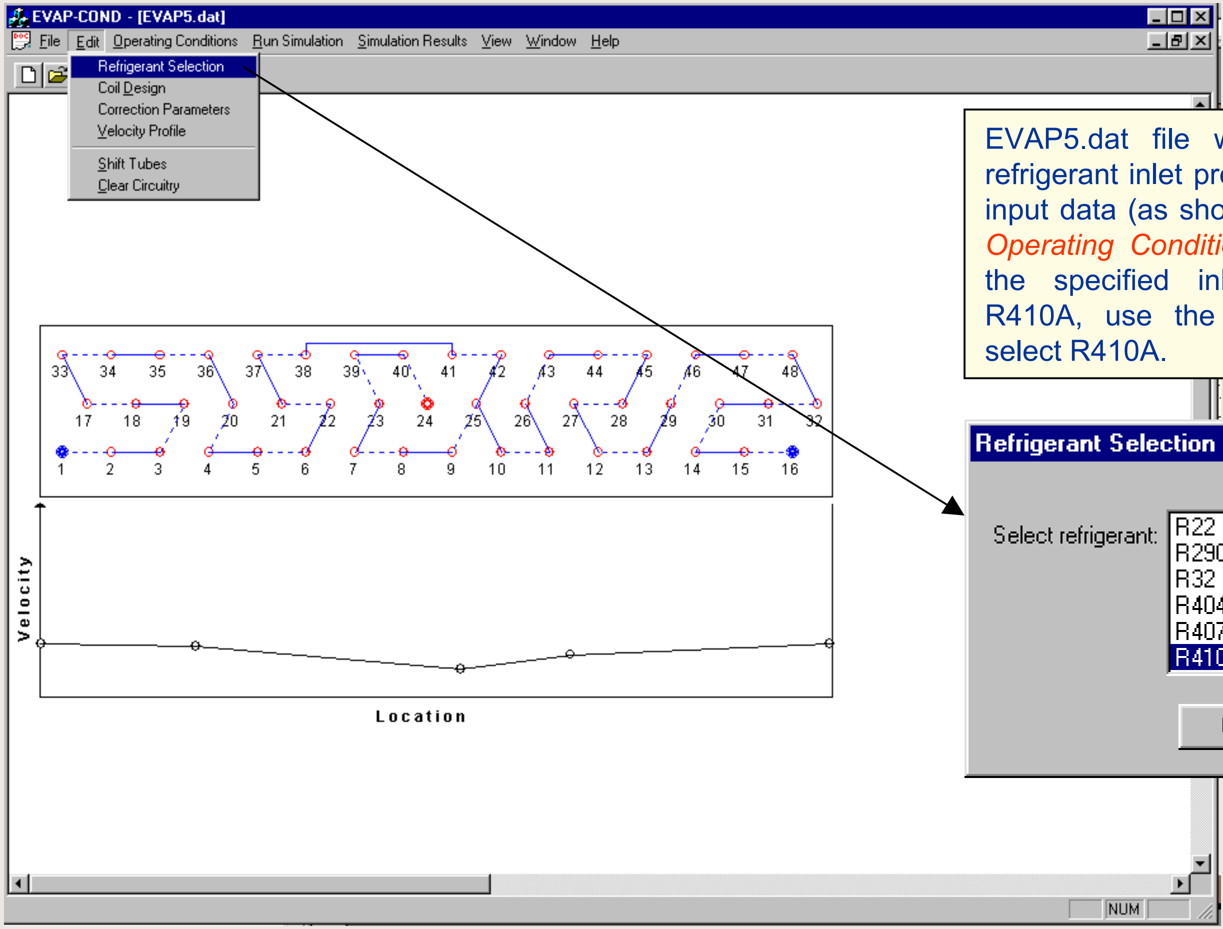
This option includes a refrigerant distributor. Condenser subcooling and evaporator superheat are imposed to be 5 ºC (9 º F).

Input includes estimated refrigerant mass flow rate, which is later iterated so the least superheated tube has the specified minimum superheat.

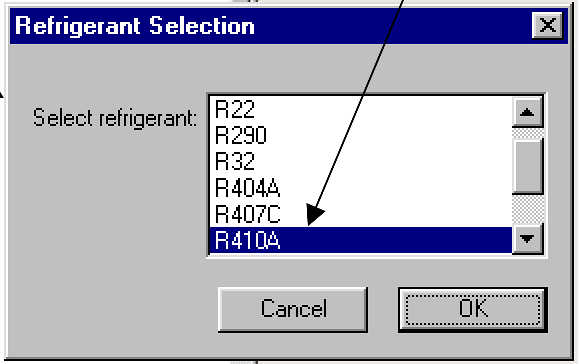
Inlet quality is imposed at 0.20.

The check mark indicates the currently selected option.

REFRIGERANT SELECTION

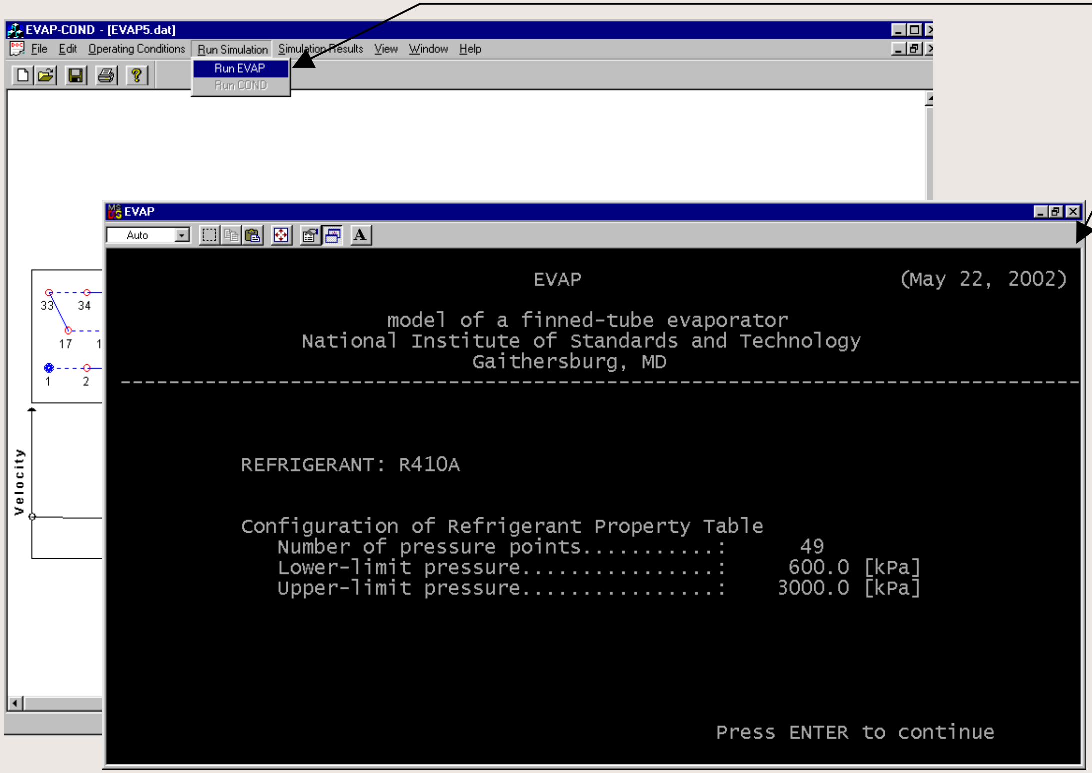


EVAP5.dat file was set up to use refrigerant inlet pressure and quality as input data (as shown in the *Evaporator Operating Conditions* window). Since the specified inlet pressure is for R410A, use the pull-down menu to select R410A.



EXECUTION OF EVAP

Once coil data and operating conditions have been specified, the interface allows simulating the evaporator.

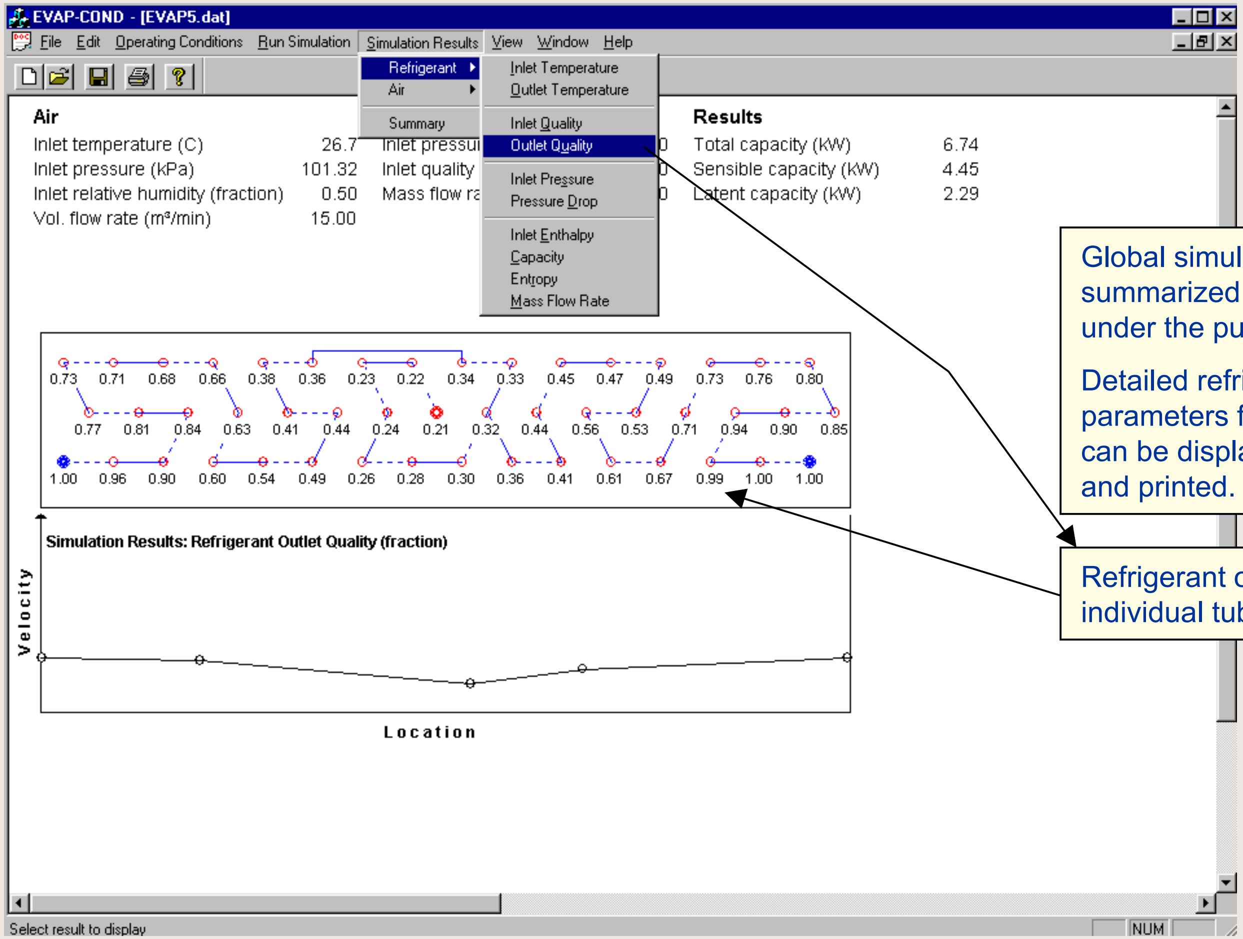


Use the pull-down menu to execute EVAP.

An MS-DOS window will appear showing the refrigerant selected and the pressure limits of the refrigerant property look-up table (more info on the following pages)

Press <ENTER> to continue with the simulation.

SIMULATION RESULTS

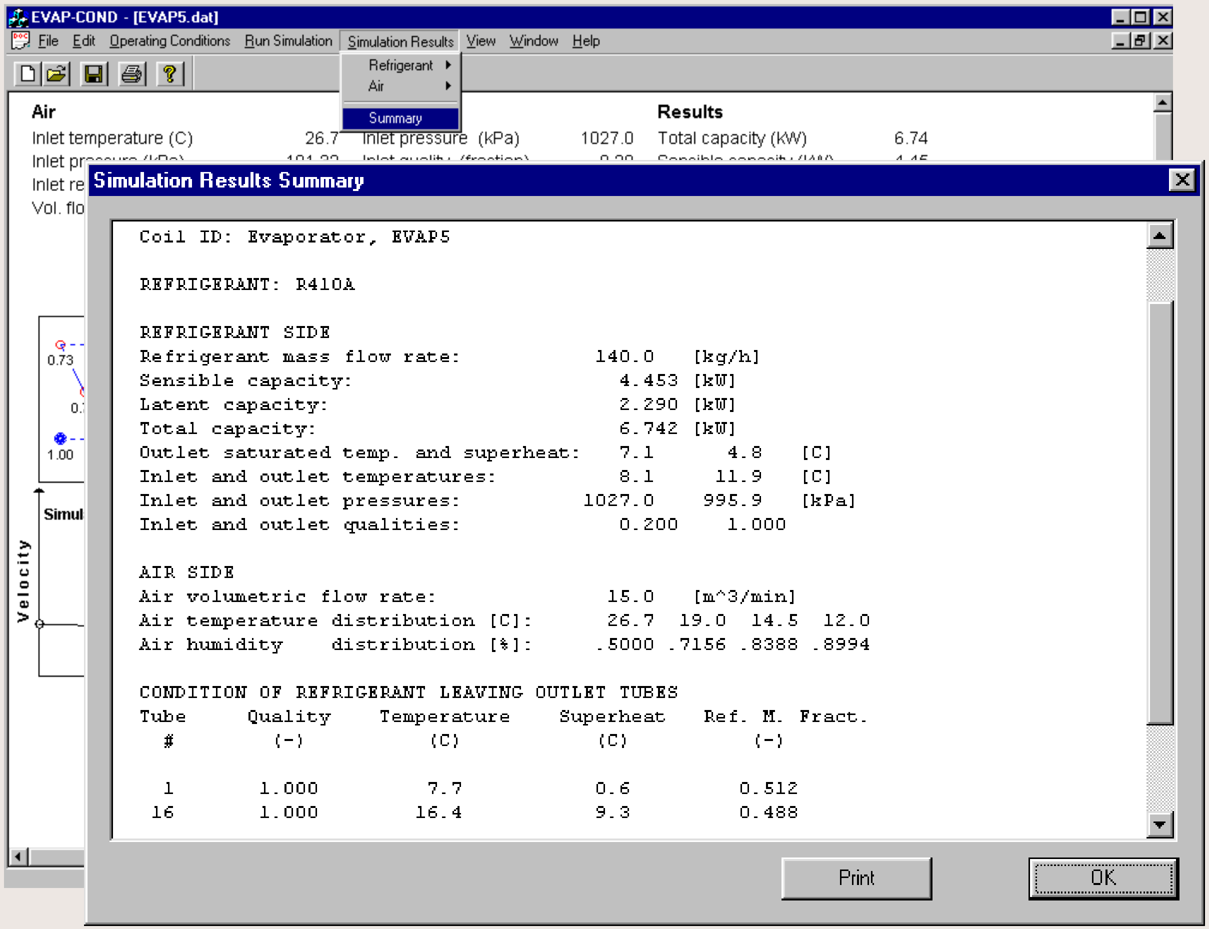


Global simulation results are summarized in the background under the pull-down menu.

Detailed refrigerant and air parameters for individual tubes can be displayed on the screen and printed.

Refrigerant outlet quality for individual tubes

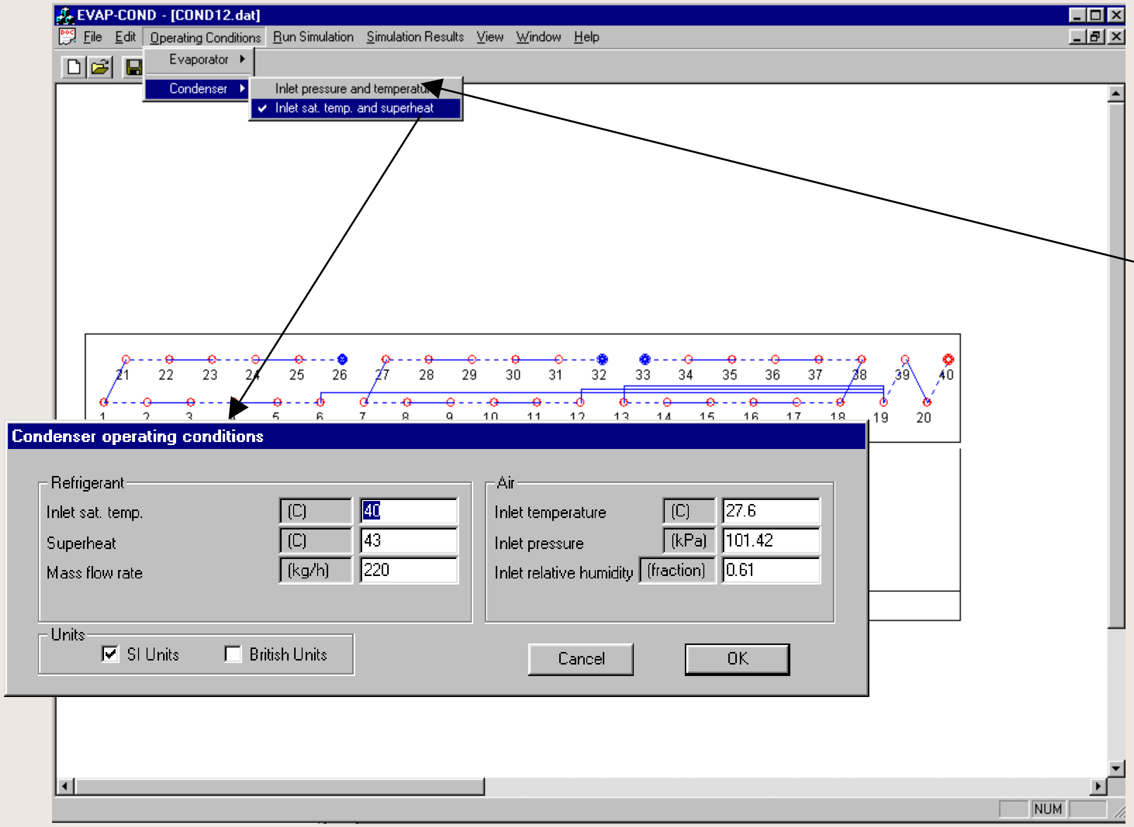
SIMULATION SUMMARY



The *Simulation Results Summary* window displays results in the units selected for the input data. The same information is written in files si.res and bt.res for the SI and Inch-Pound units, respectively.

CONDENSER OPERATING CONDITIONS

Two options for operating conditions are available for condenser simulations. All input options include air inlet temperature, pressure, and relative humidity, but they use different refrigerant parameters.



Execution of the condenser simulation model COND and data analysis is the same as for EVAP.

This option allows simulations above the critical point of refrigerant.

HOW TO SIMULATE EVAPORATOR

Summary of the tutorial using file EVAP5.dat

Run Windows Explorer and go to the directory containing EVAP-COND.exe.

Double-click on EVAP-COND.exe to start the program.

Open file EVAP5.dat to simulate the evaporator. After the file is loaded, you will see a schematic representing a side view of the evaporator. The red circle(s) indicates the inlet tube to the evaporator. The blue circles indicate the outlet tubes. The horizontal line at the bottom of the screen indicates the air velocity profile at the evaporator inlet.

Review Input Data. Click on the *Edit/Coil Design* menu item to review the evaporator design information. You may select either the SI or British system of units for your input data and simulation results.

Click on the *Edit/Operating Conditions/Evaporator/inlet pressure and quality* menu item to review operation conditions. The selected option is indicated by a check mark. Since EVAP simulates performance tube-by-tube from the inlet to outlet, the options that specify any outlet refrigerant parameter involve iterative calls to the option that specifies refrigerant inlet pressure and quality until the target outlet parameters are obtained (e.g., saturation temperature and superheat).

Click on the *Edit/Velocity Profile* menu item to review the air velocity profile. You may use the air mass flow rate specified earlier in the *Coil Design* window or integrate the air velocity profile. In general, the first option is recommended unless very detailed and accurate local measurements of the velocity profile were taken. You may change the air velocity profile using a mouse by clicking the left button.

Run a simulation. Click on the *Run Simulation* menu item and select EVAP. An MS-DOS window will appear and will give you a message when a simulation run is successfully completed.

Examine local and global simulation results. EVAP writes global simulation results to file SI.res (SI system of units) and BT.res (British system of units).

HOW TO PREPARE NEW DATA FILE

Start with *Edit/Coil Design* menu item. Input all information.

Select *Edit/Operating Conditions* menu item to input operating conditions data.

Select *Edit/Velocity Profile* to change the velocity profile using a mouse (left button).

Specify refrigerant circuitry.

If you are coding evaporator circuitry, start with one of the inlet tubes and proceed downstream. If you are coding condenser circuitry, start with one of the outlet tubes and proceed upstream, i.e., in either case you have to start from the side that is closer to the saturated liquid line.

To draw a return bend, point the mouse on a tube, press the left button, drag the mouse to the next tube, and release.

To modify the existing circuitry, double-clicking on a tube will delete the circuitry between that tube and the last tube specified for this circuit.

Once a circuit is coded, it can be used for both evaporator and condenser simulations based on specified operating conditions.

CURRENT LIMITATIONS OF EVAP- COND

- Maximum number of tubes in the heat exchanger: 130
- Maximum number of tubes in a depth row: 50
- Maximum number of tube depth rows: 5
- Maximum difference between the number of tubes in different depth rows: 1
- No empty tube locations (no missing tubes in a depth row)
- No merging refrigerant points in the evaporator circuitry; no split circuitry points in the condenser
- Minimum refrigerant temperature in the evaporator: 0 ºC (no frosting)

REFRIGERANT-SIDE CORRELATIONS

- Single-phase heat-transfer coefficient, smooth tube: McAdams, described in ASHRAE (2001)
- Evaporation heat-transfer coefficient up to 80% quality, smooth tube: Jung and Didion (1989)
- Evaporation heat-transfer coefficient up to 80% quality, rifled tube: Jung and Didion (1989) correlation with a 1.9 enhancement multiplier suggested by Schlager et al. (1989)
- Evaporation mist flow, smooth and rifled tubes: linear interpolation between heat transfer coefficient values for 80 % and 100 % quality
- Condensation heat-transfer coefficient, smooth tube: Shah (1979)
- Condensation heat-transfer coefficient, rifled tube: Shah (1979) correlation with a 1.9 enhancement multiplier suggested by Schlager et al. (1989)
- Single-phase pressure drop, smooth tube: Petukhov (1970)
- Evaporation two-phase pressure drop, smooth tube: Pierre (1964)
- Condensation two-phase pressure drop, smooth tube: Lockhard and Martinelli (1949)
- Two-phase pressure drop, rifled tube: correlation for smooth tube with a 1.4 multiplier suggested by Schlager et al. (1989)
- Single-phase pressure drop, return bend, smooth tube: White, described in Schlichting (1968)
- Two-phase pressure drop, return bend, smooth tube: Chisholm, described in Bergles et al. (1981)
  The length of a return bend depends on the relative locations of the tubes connected by the bend. This length is accounted for in pressure drop calculations.

AIR-SIDE CORRELATIONS

- Heat-transfer coefficient for flat fins: Wang et al. (2000)
- Heat-transfer coefficient for wavy fins: Wang et al. (1999a)
- Heat-transfer coefficient for slit fins: Wang et al. (2001)
- Heat-transfer coefficient for louver fins: Wang et al. (1999b)
- Fin efficiency: Schmidt method, described in McQuiston et al. (1982)

REFRIGERANT PROPERTIES

EVAP and COND use refrigerant property look-up tables to facilitate fast simulations. These look-up tables are based on pressure-enthalpy coordinates and cover the supercritical region for high-pressure refrigerants (R32, R404A, R410A, and R744). The tables cover all thermodynamic and transport properties used in simulations. They were generated by a separate program using property routines contained in REFPROP7 (Lemmon et al., 2002). The look-up scheme includes eight different property routines that retrieve the desired state or transport property depending on the available properties identifying the refrigerant's thermodynamic state.

At the outset of a simulation run, the program displays the low- and high-pressure limits of the look-up table for the refrigerant selected. For evaporator simulations, those pressures include the 0 °C – 50 °C (32 °F – 122 °F) range of saturation temperatures. For condenser simulations, the temperature range is 10 °C – 70 °C (40 °F – 158 °F). If the critical temperature of a given refrigerant (or mixture) is below 70 °C (158 °F), the look-up table extends into the supercritical region, as it is indicated by the high-pressure limit. If EVAP or COND calls for a refrigerant property that is outside the bounds of the look-up table, this property is calculated by REFPROP7 routines.

LIST OF REFERENCES

References describing EVAP, COND, and their predecessors

Domanski, P.A., and Payne, W.V., 2002. “Properties and Cycle Performance of Refrigerant Blends Operating Near and Above the Refrigerant Critical Point”, Task 2: Air Conditioner Study, report for the Air-Conditioning and Refrigeration Technology Institute, ARTI-21CR/605-50010-01-Pt.2, National Institute of Standards and Technology, Gaithersburg, MD.

Domanski, P.A., 1999, “Finned-Tube Evaporator Model With a Visual Interface”, 20th Int. Congress of Refrigeration, Sydney, Australia, September 19-24, 1999, International Institute of Refrigeration, Paris.

Domanski, P.A., 1991. “Simulation of an Evaporator with Nonuniform One Dimensional Air Distribution”, *ASHRAE Transactions*, Paper No. NY-91-13-1, Vol. 97, Part 1.

Domanski, P.A., 1989, EVSIM - An Evaporator Simulation Model Accounting for Refrigerant and One Dimensional Air Distribution, NISTIR 89-4133, National Institute of Standards and Technology, Gaithersburg, MD.

Domanski, P.A., and Didion, D.A., 1983. “Computer Modeling of the Vapor Compression Cycle with Constant Flow Area Expansion Device”, *Building Science Series 155*, National Bureau of Standards, Gaithersburg, MD.

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References on refrigerant properties, and heat transfer and pressure drop correlations

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Jung, D.S., Didion, D.A., 1989, *Horizontal Flow Boiling Heat Transfer using Refrigerant Mixtures*, ER-6364, EPRI Project 8006-2.

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Petukhov, B.S., 1970. “Heat transfer and friction in turbulent pipe flow with variable physical properties”, *Advances in Heat Transfer*, Vol. 6., p. 503-564, Academic Press, New York.

Pierre, B., 1964. “Flow Resistance with Boiling Refrigerants”, *ASHRAE Journal*, September issue.

Schlager, L.M., Pate, M.B., Bergles, A.E., 1989. “Heat Transfer and Pressure Drop during Evaporation and Condensation of R22 in Horizontal Micro-fin Tubes”, *Int. J. Refrig.*, Vol. 12, No. 1.

Shah, M.M., 1979, “A general correlation for heat transfer during film condensation inside pipes”, International Journal of Heat and Mass Transfer, 22, pp. 547-556.

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Wang, C.C., Lee, C.J., Chang, C.T., and Lin, S.P., 1999b. “Heat transfer and friction correlation for compact louvered fin-and-tube heat exchangers”, International Journal of Heat Mass Transfer 42, pp. 1945-1956.

Wang, C.C., Chi, K.Y., and Chang, C.J., 2000, “Heat transfer and friction characteristics of plain fin-and-tube heat exchangers”, part II: correlation, International Journal of Heat Mass Transfer 43, pp. 2693-2700.

Wang, C.C., Lee, W.S., and Sheu, W.J., 2001. “A comparative study of compact enhanced fin-and-tube heat exchangers”, International Journal of Heat Mass Transfer 44, pp. 3565-3573.

COMMENTS

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SUGGESTIONS

QUESTIONS

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Please E-Mail your comments on EVAP-COND to:

Piotr.Domanski@NIST.gov

We will appreciate your suggestions as to desired upgrades of the package.

Piotr A. Domanski
National Institute of Standards and Technology
Building and Fire Research Laboratory
Gaithersburg, MD, USA